MODEL 1: Sun Tracker

A sun tracker is an innovative device designed to orient an object towards the sun, maximizing the capture of solar energy throughout the day. Sun trackers are commonly used in solar panels, solar thermal collectors, and other solar energy systems to increase energy capture and overall system performance. By following the sun, trackers can significantly increase the amount of solar energy captured compared to fixed systems. Sun trackers are also used for scientific research purposes. Suntrackers use instruments like Sunphotometers to capture light intensity which in-turn are a measure of extinction of light through the atmosphere. These extinction values provide some useful information regarding the atmosphere.

This demonstration aims to illustrate a model sun tracker, showcasing its working principles, components and tracking mechanism.

Fig 1: Demonstration of Sun tracker (for illustration purposes only)

MODEL 2: Gyroscopic Flywheel stabilization (formerly Inverted Pendulum)

Gyroscopic flywheel stabilization is a fascinating principle that demonstrates how angular momentum can be used to maintain stability and resist external disturbances. In space, Satellites use reaction wheels to control their orientation. These wheels, when spun at varying speeds, create gyroscopic torques that adjust the satellite's attitude. This method allows for precise control without expending fuel, making it essential for long-term space missions.

This demonstration aims to build a simple model to illustrate the basic principles of gyroscopic flywheel stabilization. The central wheel of the model act as gyroscopes, providing stability when acted upon by a disturbance. The gyroscopic effect becomes more pronounced at higher speeds, helping the model maintain balance and making it easier to stay upright.

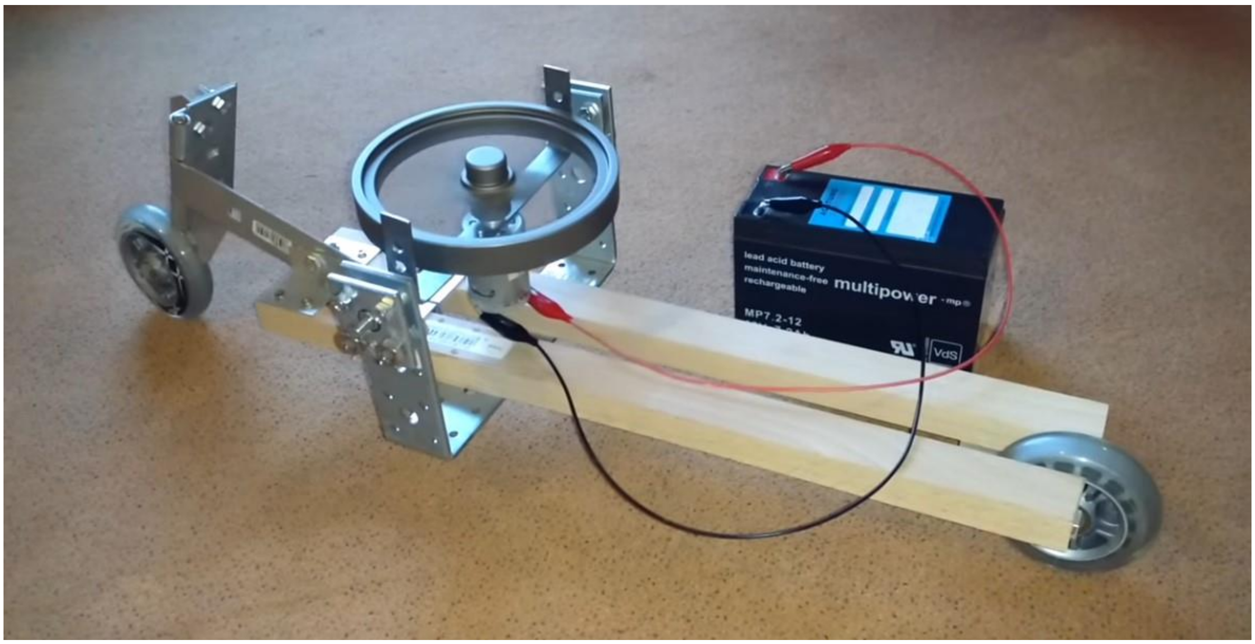
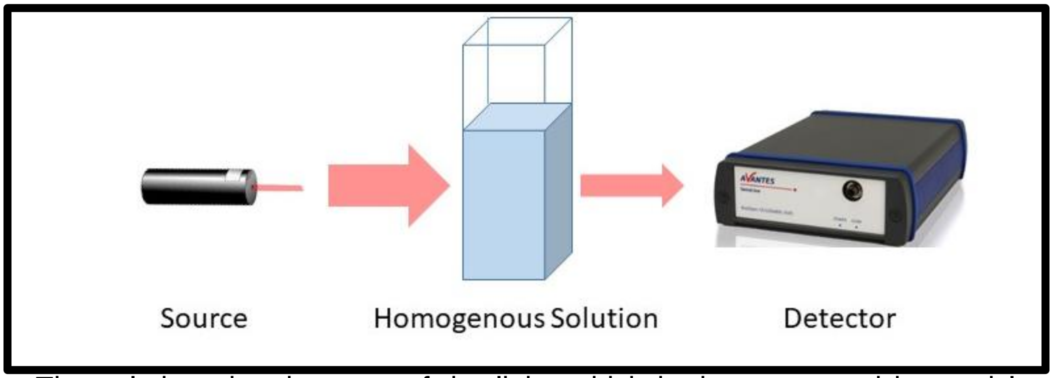


Fig 2: Demonstration of Gyroscopic Flywheel stabilization (for illustration purposes only)

MODEL 3: Light Absorption Experiment

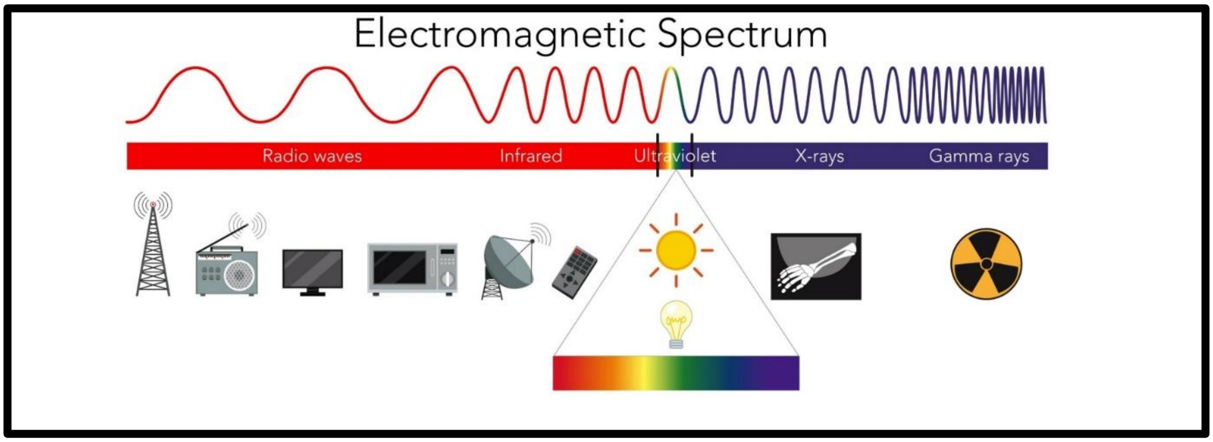
Beer-Lambert's law states that when a beam of light passes through a solution containing an absorbing substance, the rate at which the intensity of the light decreases is directly proportional to the initial intensity of the light and the concentration of the absorbing substance in the solution.



- The solution absorbs most of the light, which is then scattered by particles within the solution.
- The formula of Beer-Lambert law is given by

$$I = I_0 e^{-\mu(x)}$$

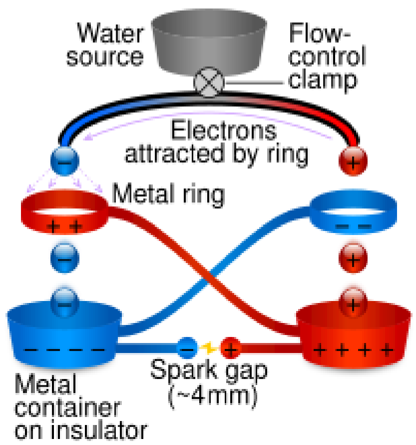
- Where I = intensity
  I_0 = initial intensity
  μ = coefficient of absorption
  x = depth in meter
- $\log\left(\frac{I}{I_0}\right) = -\varepsilon.c.x$
- I/Io ratio is influenced by absorption medium route length (l) and absorption solution concentration (c).



In this experiment, we will show spectrum of bulb/light source and absorption as per Beer-Lambert law.

MODEL 4 : Kelvin Water Dropper

OBJECTIVE - To show how falling water can generate high voltage electricity. The Kelvin Water Dropper, also known as the ***Kelvin electrostatic generator***, is an experiment designed by Lord Kelvin in 1867. This apparatus demonstrates how falling water droplets can generate high voltage electricity through the process of electrostatic induction. The experiment's main aim is to show the principles of charge separation and electrostatic induction, how these can be harnessed to generate significant voltages using simple materials.



The Kelvin Water Dropper operates on the principle of electrostatic induction. Here is a step-by-step breakdown of the process:

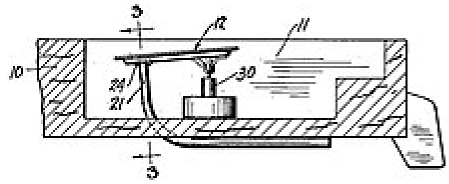
1. **Water Droplets and Induction**: As water drips from elevated reservoirs, each droplet passes through a metal ring (inductor). The falling droplets interact with the metal ring, inducing a small charge in it. Because the collectors are cross connected to the opposite inductors, this initial small charge is essential in starting the induction process.
2. **Charge Amplification**: With each successive droplet, the induced charges on the inductors are transferred to the collectors. This cross-connection ensures that one collector becomes increasingly positive while the other becomes increasingly negative.
3. **Feedback Loop**: The setup forms a feedback loop, where the increasing charge on the collectors enhances the induction effect in the rings, further amplifying the charge separation with each falling droplet.
4. **High Voltage Generation**: As the process continues, the voltage difference between the two collectors builds up, potentially reaching several thousand volts. This high voltage is due to the continuous and cumulative effect of charge induction and separation.

It demonstrates how natural processes, such as falling water, can be harnessed to generate significant electrical potential. This principle is analogous to natural phenomena like thunderstorms, where similar processes lead to the build-up of static electricity and eventual lightning.

MODEL 5: Pop Pop Boat

OBJECTIVE - To demonstrate the conversion of thermal energy into mechanical motion using a simple steam-powered boat.

The pop-pop boat, also known as the putt-putt boat, is a toy that demonstrates basic principles of steam power. The pop-pop boat operates on the principle of steam propulsion. Water inside the boiler is heated to produce steam, which creates pressure that is expelled through an exhaust pipe, propelling the boat forward. The steam then condenses, creating a vacuum that draws in more water and repeats the cycle, producing a rhythmic pop-pop sound.



https://upload.wikimedia.org/wikipedia/commons/thumb/f/f6/Jonespoppop.JPG/220px-Jonespoppop.JPG

Concept and Mechanism

The pop-pop boat operates on a simple steam engine mechanism. Here's a detailed explanation of how it works:

1. **Heat Source**: A small candle or other heat source is placed under a thin metal boiler (often a small metal tube or a flat, enclosed chamber). This heat source warms the water inside the boiler.
2. **Steam Generation**: As the water heats up, it turns into steam. The steam expands and increases the pressure inside the boiler.
3. **Propulsion**: The high-pressure steam is forced out through a small exhaust pipe. This release of steam pushes against the water, propelling the boat in the opposite direction, according to Newton's third law of motion (for every action, there is an equal and opposite reaction).
4. **Condensation Cycle**: As the steam exits and comes into contact with the cooler water outside, it condenses back into liquid. This condensation creates a vacuum inside the boiler, reducing the internal pressure.
5. **Water Intake**: The vacuum draws more water into the boiler through the exhaust pipe. This cycle of heating, steam generation, and condensation repeats rapidly.
6. **Continuous Motion**: The repeated cycle of steam expulsion and water intake causes the boat to make a rhythmic pop-pop sound and moves it forward continuously.

MODEL 6: Messengers from the Earth' Interior

The planet Earth is made up of three internal layers: the uppermost elastic layer called the CRUST, the middle plastic layer the MANTLE and the innermost metallic layer called the CORE. The crust is made up of solid rocks like granites and basalts, and can continental (0-35 km) or oceanic (0-8 km). We can study and understand the crust because it can be directly sampled on the surface; however, the mantle (35-2900 km) and the core (2900-6400 km) too deep to access. Therefore, to study the interior of the Earth we reply on certain massagers from the deep. Some of them are shown below. **Volcanoes** bring in material from the Earth's mantle in form of molten rocks or lavas. They also bring in **Gases** such as CO_2, SO_2, H_2O etc. from deep interior. Sometime these lavas can bring in pieces of mantle rocks in form of **Xenoliths**. Sometime molten mantle rocks get extracted from very deep inside as **Kimberlites**, which also bring in **Diamonds** to the surface. Samples of these messengers are studied using the optical properties of minerals present (in **Thin-sections**). Their chemical and isotopic compositions are utilized to determine their age, origin and evolution, which in turn helps us understand the evolution of Earth's interior through time since its formation 4.56 billion years ago.

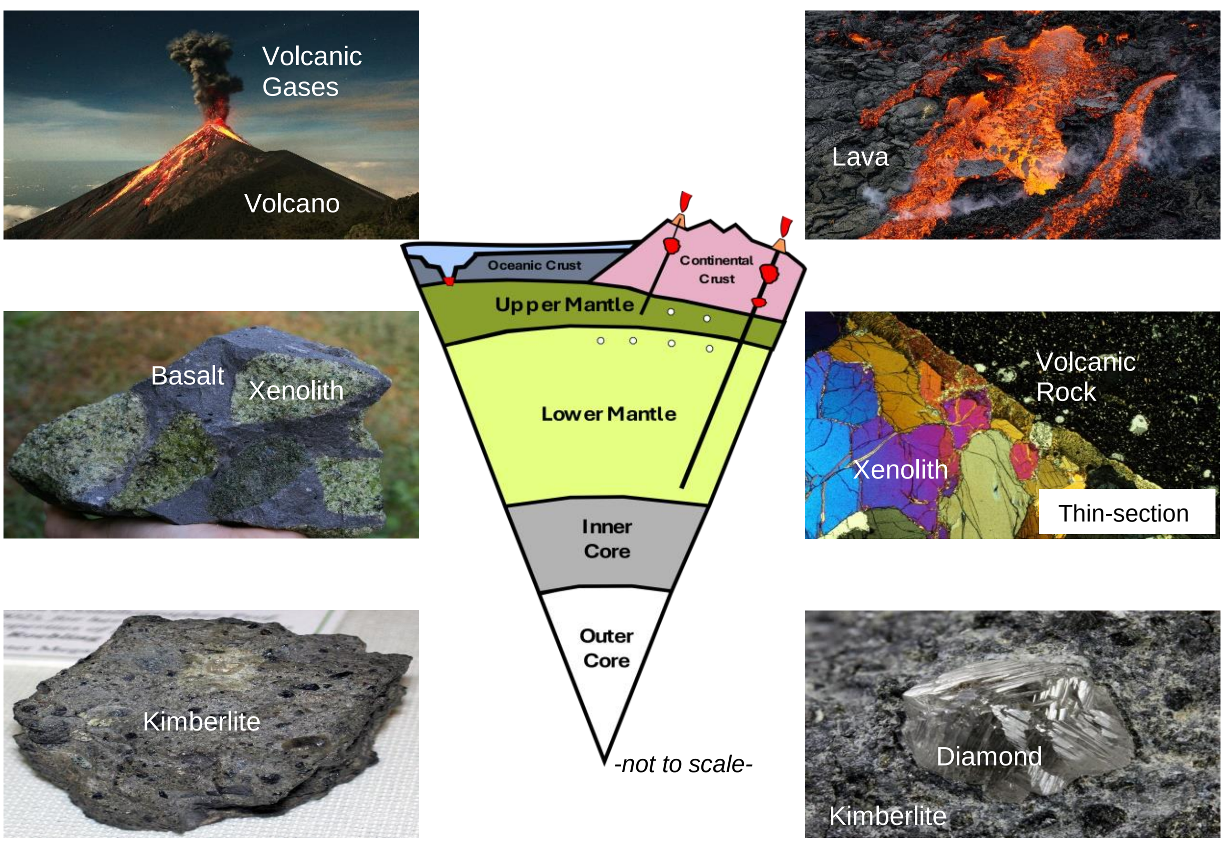
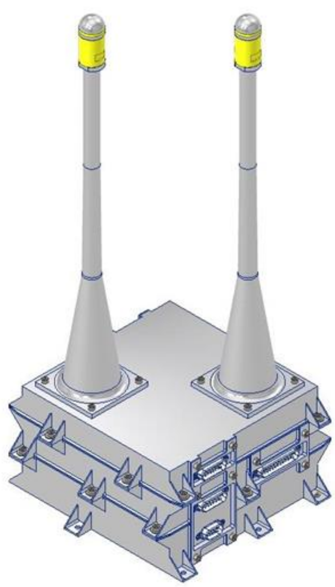


Figure. Diagram of the Earth's cross-section, and various messengers from interior of the Earth.

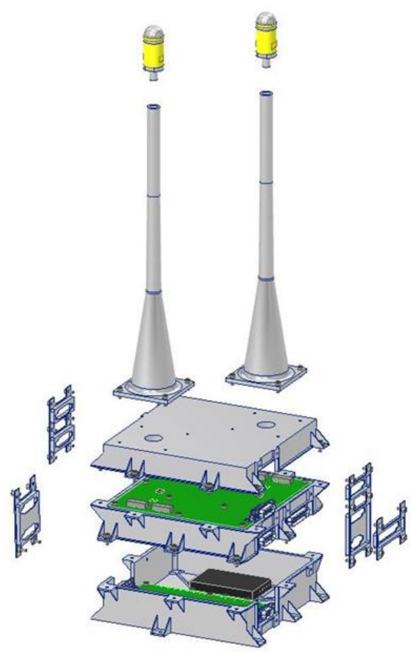
Model 7: Langmuir Probe (LP) payload for future DISHA mission

The Langmuir Probe (LP) payload, part of the upcoming DISHA mission, is designed to provide high-resolution measurements of plasma density and fluctuations in the ionosphere. This payload aims to measure the ionospheric plasma (electron) density (N_e) and changes in plasma density (ΔN_e). It will help scientists understand the physical processes that generate plasma irregularities and plays a crucial role in characterizing fundamental processes associated with plasma turbulence in the ionosphere. These measurements are crucial for applications in telecommunications and navigation. The Langmuir Probe's innovative design features a hemispherical sensor accompanied by a guard ring, which enhances temporal response and minimizes leakage current. This unique configuration allows the probe to operate in a high-frequency mode, enabling the direct measurement of changes in plasma density (ΔN_e).

The Langmuir Probe payload includes two sensors mounted in the ram direction of the satellite. With these two sensors, the system can function seamlessly in different modes, including sweep and fixed bias voltage applications. The photos below showcase the detailed mechanical design of the Langmuir Probe. The first image shows the entire Langmuir Probe assembly, including the sensor, electronics stack, and mounting hardware, highlighting the integration of various components. The second image provides an exploded view of this assembly, allowing for a better understanding of the packaging of each component inside the mechanical housing.



CAD model of the LP payload

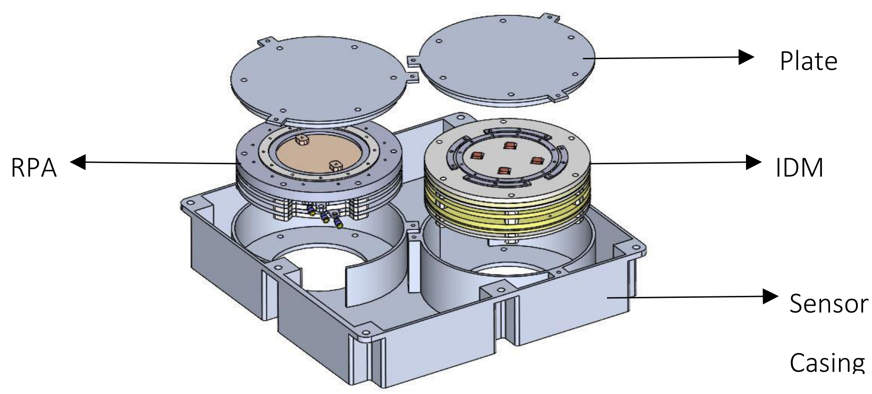


Exploded view of LP mechanical assembly

Model 8 : Drift Meter (DM) payload for future DISHA mission

The Drift Meter (DM) payload, which will be flown onboard the upcoming DISHA mission, will measure one of the fundamental ionospheric parameters, namely the Ion Drifts, the knowledge of which is essential to understand the ionospheric electrodynamics unambiguously. The earth is a magnetized body and its upper atmosphere consists of thermosphere and ionosphere, which refer, respectively, to the regions of very high temperature of gases and ionized plasma. The ionosphere and thermosphere occupy the same volume and are strongly coupled with one another due to plasma neutral interactions. The plasma motions are guided by the presence of electric and magnetic fields, while that of the neutrals are driven by winds. However, due to the ion-neutral coupling, the motions of plasma and neutrals are intricately coupled with each other, as a result of which a host of electrodynamic processes get generated. Hence, for the understanding of all the ionospheric electrodynamical phenomena, the knowledge of electric fields/ion drifts is extremely essential. The measurements from the DM on board DISHA will thereby form the cornerstone in the understanding of ionospheric electrodynamics during periods of both geomagnetic quiet and space weather disturbances.

The suite of the DM payload consists of two subsystems, namely Retarding Potential Analyzer (RPA) and Ion Drift Meter (IDM), which need to be placed in the ram direction of the satellite. While the RPA measures the bulk ion velocities along the ram direction, major ion densities and ion temperatures, IDM will measure ion arrival angles in the directions orthogonal to that of ram. The ram ion velocities obtained from RPA can then be used with the ion arrival angles to obtain ion drift velocities in the transverse direction. Thus the DM payload will help obtain a complete picture of the ion drifts, along with major ion densities and ion temperature.



Drift Meter Sensor Assembly

Model 9: Airglow Photometer (AP) payload for future DISHA mission

The Airglow Photometer (AP) payload, part of the upcoming DISHA mission, is designed to provide measurements of airglow emission intensities of the O I 630 nm and O I 777.4 nm lines. This payload aims to measure the intensities of each of these lines in two different directions through a V-shaped 2-arm configuration. Each arm would act as an independent instrument to provide data which would provide information about the altitudinal profile of the emission, latitudinal variation in the emission intensity and over long-term observation it would give insight on the seasonal and solar cycle effects on airglow intensity. By measuring these emissions emanating from two different heights (630.0 nm from ~250 km and 777.4 nm from ~350 km), AP will also capture the altitudinal variations of the local ionospheric processes as well as the impact of space weather processes.

The Airglow Photometer payload has four arms, each with an independent opto-mechanical and CMOS detector system, as shown in Figure 1, pointed towards the negative pitch direction of the satellite's motion. Figure 2 shows the mechanical design of the payload, including the four arms, electronics box, and mounting hardware, highlighting the integration of various components. Figure 3 provides an exploded view of one arm for a better understanding of the packaging of each component inside the mechanical housing.

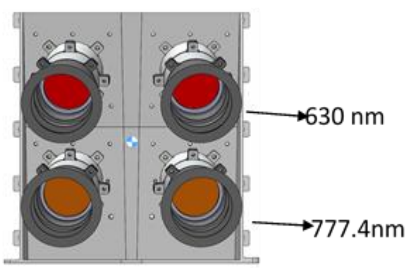


Figure 1: Four arms of the payload

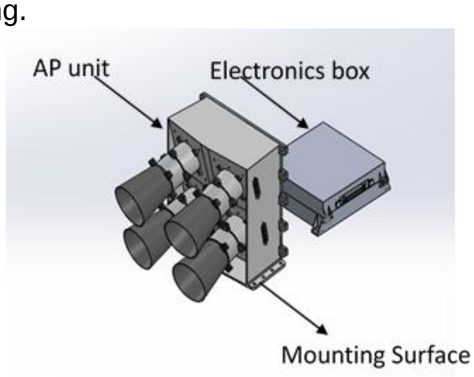


Figure 2: Mechanical assembly of payload

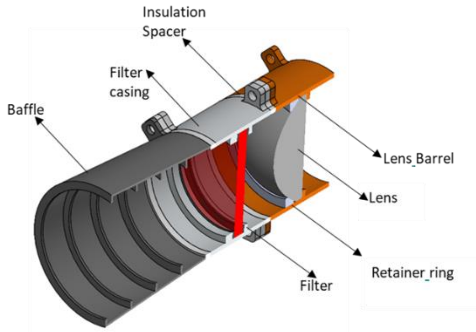
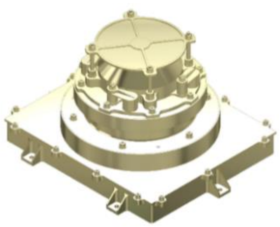


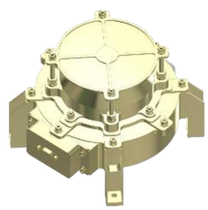
Figure 3: Opto-mechanical design of one arm

Model 10: ASPEX-SWIS on-board Aditya-L1

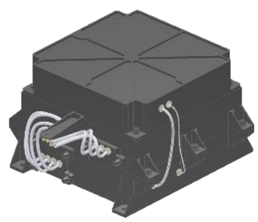
The Aditya Solar Particle EXperiment payload is one of the seven scientific payloads on board Aditya–L1 mission, designed to measure low and high-energy particles associated with various solar wind components and phenomena. It aims to differentiate between slow and fast solar wind components, suprathermal populations, Alpha and Proton abundances, particles accelerated by Coronal Mass Ejections (CMEs) and solar energetic particles (SEPs). The instrumentation of ASPEX, including SWIS (Solar Wind Ion Spectrometer) and STEPS (Supra-Thermal Energy Particle Spectrometer), is tailored to address the above science objectives comprehensively. SWIS is a low energy ion spectrometer measures ion flux in the range of 100 eV - 20 keV, while STEPS is a high energy spectrometer works in the energy range of from 20 keV/n up to 5 MeV/n. Solar Wind Ion Spectrometer (SWIS) payload measure solar ion flux in and across ecliptic plane. It consists of four packages: Top Hat Analyzer-1, Top Hat Analyzer-2, High Voltage and Processing Electronics. THA-1 is capable of measuring the angular distribution of particles arriving in the ecliptic plane with species separation. It has Electrostatic Analyzer (ESA), Magnetic Mass Analyzer (MMA) and MCP with 16 sector RAE with angular resolution of 22.5 degree. THA-2 is capable of measuring the angular distribution of particles.



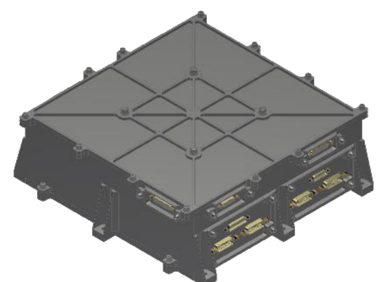
THA-1



THA-2



High Voltage



Processing Electronics

MODEL 11: Vertical profile measurements of Ozone - Ozonesonde Experiment

Ozone is one of the most significant trace gases in the atmosphere. In the stratosphere, it acts as a shield blocking harmful UV radiation from reaching the Earth whereas in the troposphere, it is an important greenhouse gas as well as a pollutant near the surface. Measurements of vertical profiles of ozone are important in studying its contribution to atmospheric warming and the impacts of human intervention on the vertical distribution of ozone.

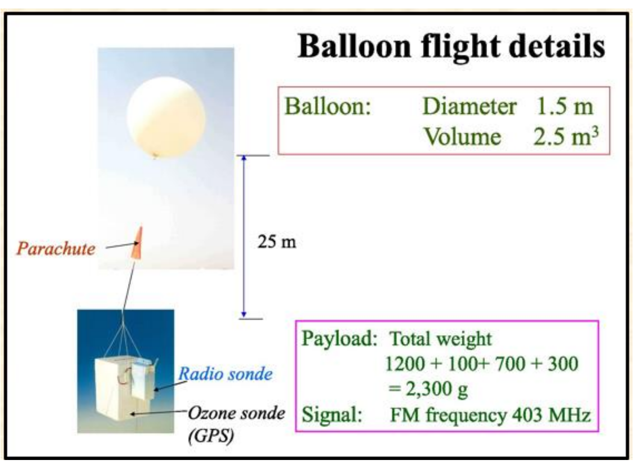
The **ozonesonde**, carried on a radiosonde balloon, is used to conduct in-situ measurements of the vertical profiles of ozone with high vertical resolution throughout the troposphere and lower-mid stratosphere.

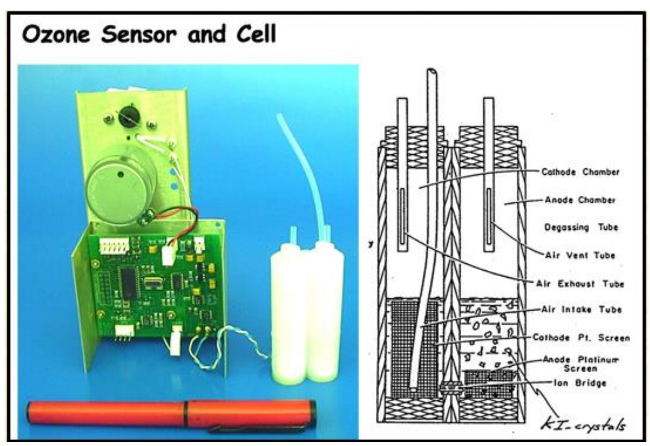
Working principle: The sensor consists of two electrolytic cells, each containing a solution of potassium iodide (KI) at different concentrations. The cells are initially in chemical and electrical equilibrium. However, when an air sample containing ozone is drawn into one of the cells using a Teflon pump, the equilibrium is perturbed due to reaction between KI and ozone and an electric current flow between the cells.

$$2\mathrm{KI} + \mathrm{O_3} + \mathrm{H_2O} \rightarrow 2\mathrm{KOH} + \mathrm{I_2} + \mathrm{O_2}$$

$$\mathrm{I_2} + 2e \rightarrow 2\,\mathrm{I^-}$$

The amount of electric charge, which is proportional to the partial pressure of the ozone in the ambient air, is continuously transmitted to a ground station along with the ambient pressure, temperature, relative humidity, and GPS parameters.





Model 12: Non-Newtonian fluid

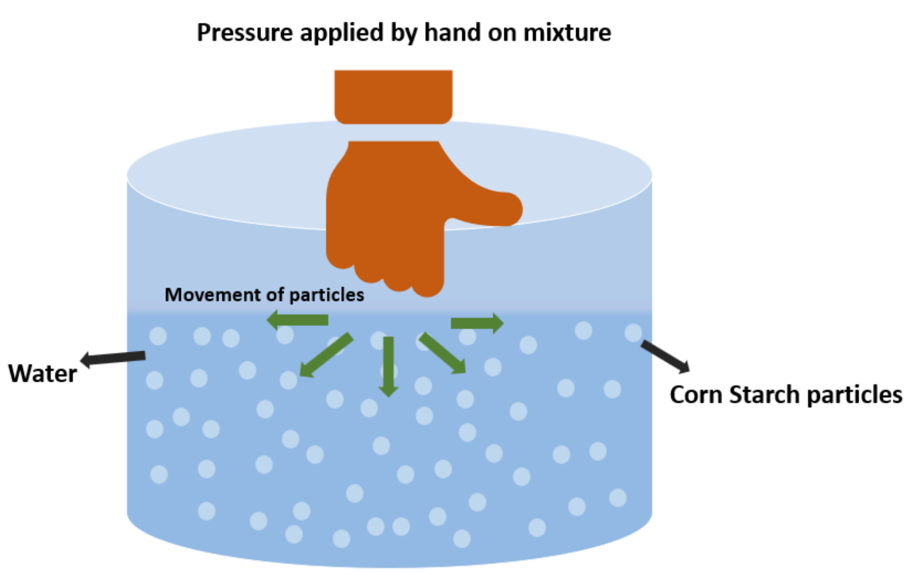
Non-Newtonian fluids, such as a cornstarch and water mixture, display unique behaviour that differs from typical fluids. These mixtures become more viscous or solid-like under stress or impact but flows easily when left undisturbed. This behaviour occurs because the starch particles in the mixture rearrange under force, resisting flow. When quickly punched or squeezed, it feels hard, but when slowly moved through, it acts like a liquid.

A non-Newtonian fluid is a fluid that does not follow Newton's law of viscosity, that is, it has variable viscosity, dependent on stress. In particular, the viscosity of non-Newtonian fluids can change when subjected to force. Many salt solutions are non-Newtonian fluids, as are many commonly found substances such as custard, toothpaste, starch suspensions, corn starch, paint, blood, melted butter, and shampoo.

Newton's Law of Viscosity states that the shear stress between adjacent layers of a fluid is directly proportional to the velocity gradient between those layers. Mathematically, it can be expressed as:

$$\tau = \mu \frac{du}{dy}$$

where, τ is the shear stress between two layers of the liquid, μ is the coefficient of viscosity and $\frac{du}{dy}$ is the velocity gradient. However, the non-Newtonian fluids do not obey this law.



Non-Newtonian Fluid

MODEL 13: Glass Blowing Experiment

We are specialized in high vacuum systems for sample processing and purification, utilizing a range of sophisticated equipment. Many of our systems are custom-designed using glass tubes, stopcocks, and vacuum pumps. We employ traditional glassblowing techniques to shape and join glass components using flames, ensuring precision and functionality. This combination of technical skill and creativity allows us to create tailored glass vacuum systems that are essential for our laboratory's daily operations.

Below is a depiction of a glass vacuum system designed and developed at PRL's Radiocarbon Dating Laboratory

MODEL 14 : Liquid Nitrogen Experiments

For our daily laboratory experiments, especially for cryogenic gas separation, we utilize liquid nitrogen. Liquid nitrogen is the liquid form of nitrogen gas and exists at an extremely low temperature (-196°C). It is colorless, odorless, and inert, making it a versatile substance with numerous applications across various fields. Due to its low temperature, liquid nitrogen must be stored in specially designed insulated containers called dewars. These containers minimize heat transfer and prevent the nitrogen from vaporizing quickly.

Applications

- Liquid nitrogen is extensively used in cryogenic distillation, a process that leverages extremely low temperatures to separate gases according to their different boiling points. For instance, in separation of carbon dioxide (CO_2) from a gas mixture, CO_2 (with a boiling point of -78 °C) condenses into dry ice at liquid nitrogen temperature, while other gases like nitrogen and oxygen remain in gaseous form and can be pumped. This method allows for the quantitative separation of CO_2 from the gas mixture.
- Here, a simple experiment with liquid nitrogen is demonstrated. Typically, when air is blown into a balloon, it inflates. However, if the balloon is partially submerged in liquid nitrogen, it contracts. This occurs because the air inside the balloon compresses as the temperature drops. Once the balloon is removed and warms up, the air inside expands again, causing the balloon to re-inflate.
- Liquid nitrogen is also utilized to cool superconductors, conduct experiments in low-temperature physics, and rapidly chill samples for various analytical techniques.
- Liquid nitrogen is widely used for preserving biological samples, such as cells and tissues.
- Liquid nitrogen is also used to make materials brittle and break easily. When some materials are cooled to liquid nitrogen temperature, their physical properties get altered. For example, when a rubber ball or a piece of rubber tubing is immersed in liquid nitrogen, it becomes extremely brittle. Once removed from the liquid nitrogen, the rubber can be easily shattered or broken into pieces with minimal force.

Model 15: Radiocarbon Dating

This model illustrates the principle of radiocarbon dating. Radiocarbon (14C) is the natural radioactive isotope of carbon produced in the upper atmosphere when cosmic rays interact with nitrogen atoms, creating 14C that then oxidizes to form 14CO2. This 14CO2 mixes with atmospheric CO2 and becomes part of the carbon cycle, being absorbed by living organisms. While an organism is alive, it maintains a constant level of 14C due to a balance between intake and decay. Upon death, it stops absorbing 14C, and the existing 14C atoms begin to decay at a known rate with a half-life of 5,730 years. By measuring the remaining 14C in a sample (e.g., charcoal, wood, bone, shell, sediment etc.) and comparing it to the initial 14C content, scientists can estimate the time elapsed since the organism's death.

In the ocean, 14C enters through the exchange of atmospheric CO2 with seawater. As 14C dissolves into seawater, it is incorporated into marine organisms via photosynthesis and food chains. Phytoplankton absorb 14C, which then moves through the marine food web. Analysing the distribution and concentration of 14C in oceanic environments can reveal information about ocean circulation patterns, carbon cycling, and the age of marine sediments.

We use Accelerator Mass Spectrometry to measure 14C contents in a sample.